Compositional Analysis and Provenance of Ice Rafted Debris Site 580 Deep Sea Drilling Project.

by
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Approved by Lawrence Krissek

Acknowledgements

Thanks to my advisor Dr. Lawrence Krissek for getting me started on this thesis and periodically showing me the way back to reason.

Thank you to my parents and family for putting up with me all of these past few years.

Table of Contents

LIST OF FIGURES

INTRODUCTION

Setting of Site 580

Site 580 is one of many ocean floor cores taken by the Deep Sea Drilling Project (DSDP). Operations at Site 580 included 155.3 meters of continuous coring. Of this 155.3 meters, 91% was recovered, logged, and analyzed by the DSDP Leg 86 shipboard scientific party (1985). One goal of Leg 86 was to better define paleoenvironments of the northwestern Pacific Ocean (Heath, Burckle, et al., 1985). To this end, scientists on DSDP Leg 86 drilled at four sites between the Kamchatka Peninsula and northern Japan. Samples I have used for this thesis were taken from the sediments drilled at Site 580 between the Kuril-Kamchatka Trench and the Shatsky Rise. Today Site 580 lies directly under the subarctic front, which is the primary region in the North Pacific dividing cold arctic water from the warmer subtropical waters to the south (Heath, Burckle, et al., 1985). The subarctic front is currently marked by siliceous microfossil deposition to the north and carbonate microfossil deposition to the south. It is possible that ice rafted debris type and abundance can also be used as an indicator of the location and strength of the current. Although Site 580 has been steadily moving northward due to tectonic motion (Krissek, 1986), it can be treated as stationary with the subarctic passing over.

Geographically site 580 is located at 41 37.47' North Latitude and 153 58.58' East Latitude. This is a reasonably good location for analyzing the occurrence and abundance fluctuations in ice rafted debris (IRD; Krissek et al., 1985). Figure 1 shows the position of Site 580 relative to possible source areas of ice rafted debris. Due to its distal location Site 580 will receive IRD only during periods of maximum iceberg production. This is reflected by the zone of "Rare Rafting" shown on the map reproduced from Carney (1986). For these reasons, Site 580 should also be an excellent location to look for qualitative changes in IRD composition because it is positioned at the confluence of the Sea of Okhotsk with the Pacific Ocean. Depending on the position of the subarctic front, Site 580 can receive ice rafted debris from either the northern coast of Siberia or the coast of the Sea of Okhotsk. Any specific changes in the lithology of IRD accumulating on the ocean floor can be delineated and possibly used to interpret temporal variation in continental source area and North Pacific paleocurrents.

Past Work

A number of analysis have already been conducted on the sediments obtained at Site 580. The shipboard scientific party determined gross lithostratigraphy through macroscopic and petrographic smear slide analysis. Biostratigraphic, geochemical, heat flow, shear strength, and gravimetric measurements were also made (Heath, Burckle, et al., 1985). Based on this analysis it was determined that the sediments at Site 580 form a single siliceous clay unit that can be separated into five subunits based upon slight changes in grain mineralogy or biogenic abundance (Heath, Burckle, et al., 1985). My analysis is restricted to the upper subunit so that the unit divisions need not be discussed further.

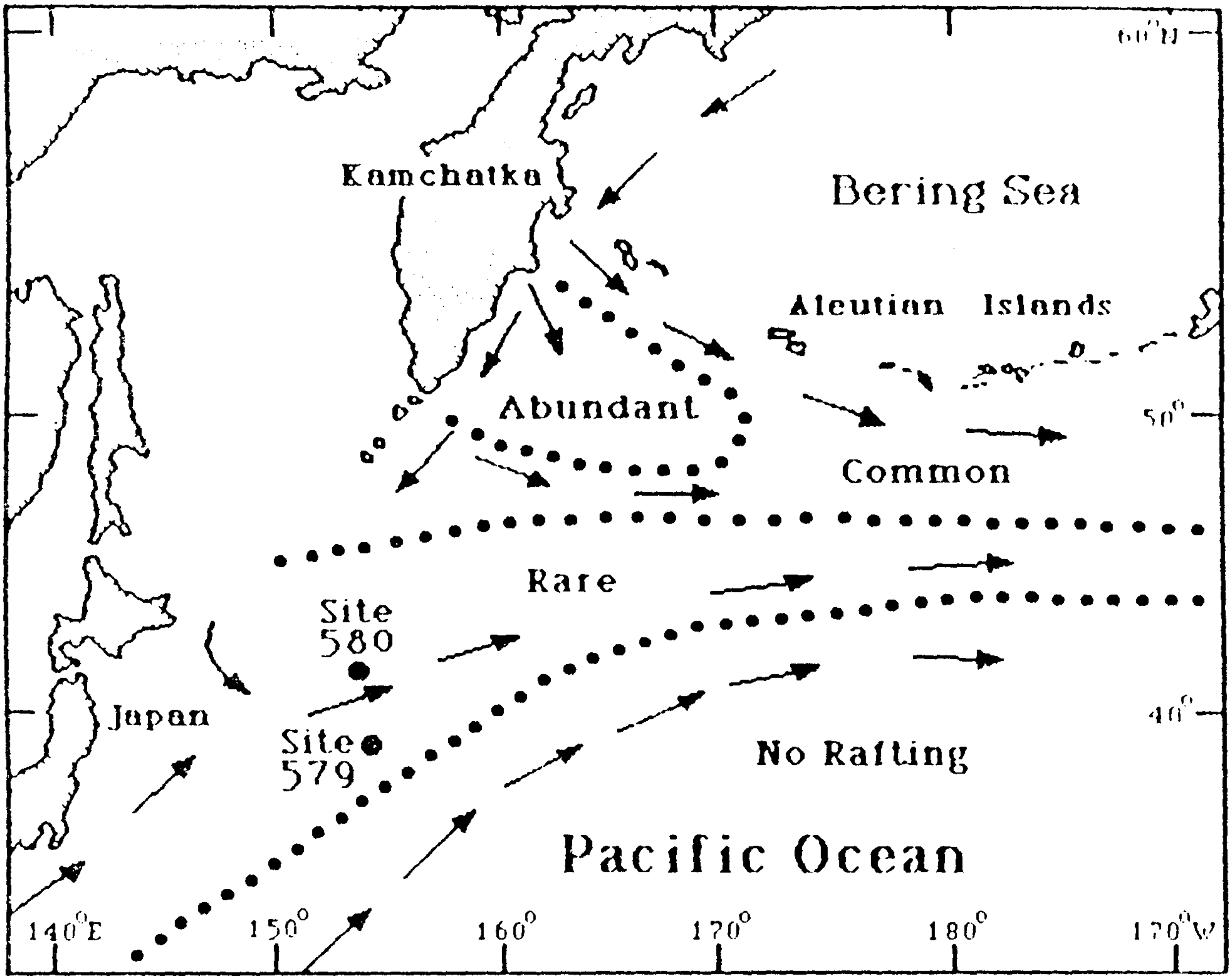


Figure 1. Map of Northwest Pacific showing Site 580, prevailing currents, and zones of relative ice rafting intensity. From Carney (1986).

Geology of Source Area

On the basis of previous studies of IRD in the Northwest Pacific (Kent, Updike, and Ewing, 1971), ice rafted debris at Site 580 is expected to have originated from the Northwest Pacific source areas in the Kamchatka Peninsula, northeastern Siberia, the Kuril Islands, and Sakhalin Island. The stratigraphy of these areas is extremely varied and has been poorly investigated. However, there is sufficient data to make rough regional geologic representations of the areas (Figure 2).

Kamchatka

The Kamchatka Peninsula lies off the northeastern coast of Siberia. It is associated with the Kuril-Kamchatka Trench, and is extremely volcanically active. Kamchatka is dominated by a range of central island arc volcanic mountains. These ridges are largely composed of basalts and andesites. The central range runs northeastward into the Koryakskii Range of extreme northeastern Siberia.
Both ranges are surrounded largely with lower and upper cretaceous strata. Due to intense volcanic activity these strata have been metamorphosed into marble and quartzite with minor slate.

Off the west coast of Kamchatka lies the Sea of Okhotsk. This sea is characterized by an extremely shallow northern end, progressing to a rather deep confluence with the Pacific Ocean at the Kuril-Kamchatka Trench (Figure 3). Lithologies in western Kamchatka include interbedded conglomerate, sandstone, carbonate and shale sequences of Pliocene and Quaternary age (D'yakov, 1956). Many of these beds have undergone moderate to high grade metamorphism depending on their proximity to the east-central volcanic belt. Volcanic influence increases northward from central Kamchatka (D'yakov, 1956). Eastern Kamchatka holds minor siliciclastic sedimentary and metamorphic sequences along the coastline and the area is dominated by volcanic activity (D'yakov, 1956). Kamchatka is an excellent source for the sedimentary/metamorphic siliceous, carbonate, and mafic ice rafted debris I have identified. However, the eastern coast is dominated greatly by volcanic activity so it is much more likely that non-igneous IRD originated on the western coast.

Kuril Islands

The Kuril Islands are composed completely of volcanics and Cenozoic strata. The southern Kuril islands are made up of andesites and volcanic tuff layers while the northern section is largely tuffaceoues breccias and marine sandstone interbedded with andesite-basalt volcanics (Nikol'ski, 1959). These islands are a possible source of mafic and siliceous ice rafted debris. Carbonate rocks, however, are not present.

Okhotsk Region

The western coast of the Sea of Okhotsk is bordered by the Dzhugdzhur Range. This area is primarily composed of exposed granitic batholithic cores that create a large escarpment. Granitic IRD is rare at Site 580 and this is not surprising considering the greatly increased distance of transport to possible sources of granite. The northwestern shore of the Sea of Okhotsk is the only locality with large occurrences of exposed granitic basement and therefore is the most likely source of granitic IRD deposited at Site 580.

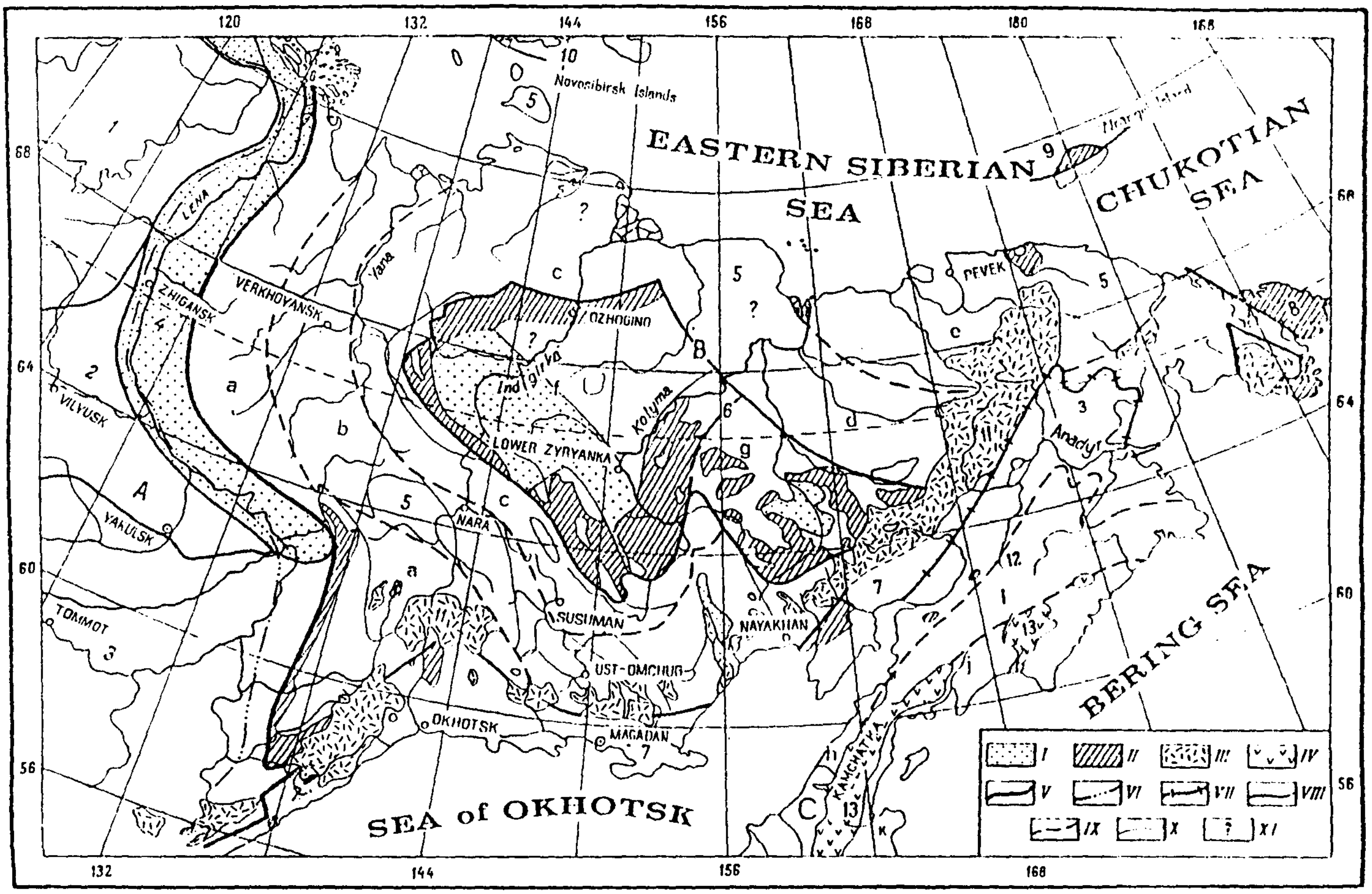


Figure 2. Geologic map of northern Russia. III=Dzhugdzhur Range, granitic pluton; C=Cenozoic sedimentary sequences; k=Cenozoic metamorphosed and sedimentary; 13=Central Kamchatka Range, mafic volcanic. From Nalivkin, <u>Geology of the U.S.S.R.</u>, (1973).

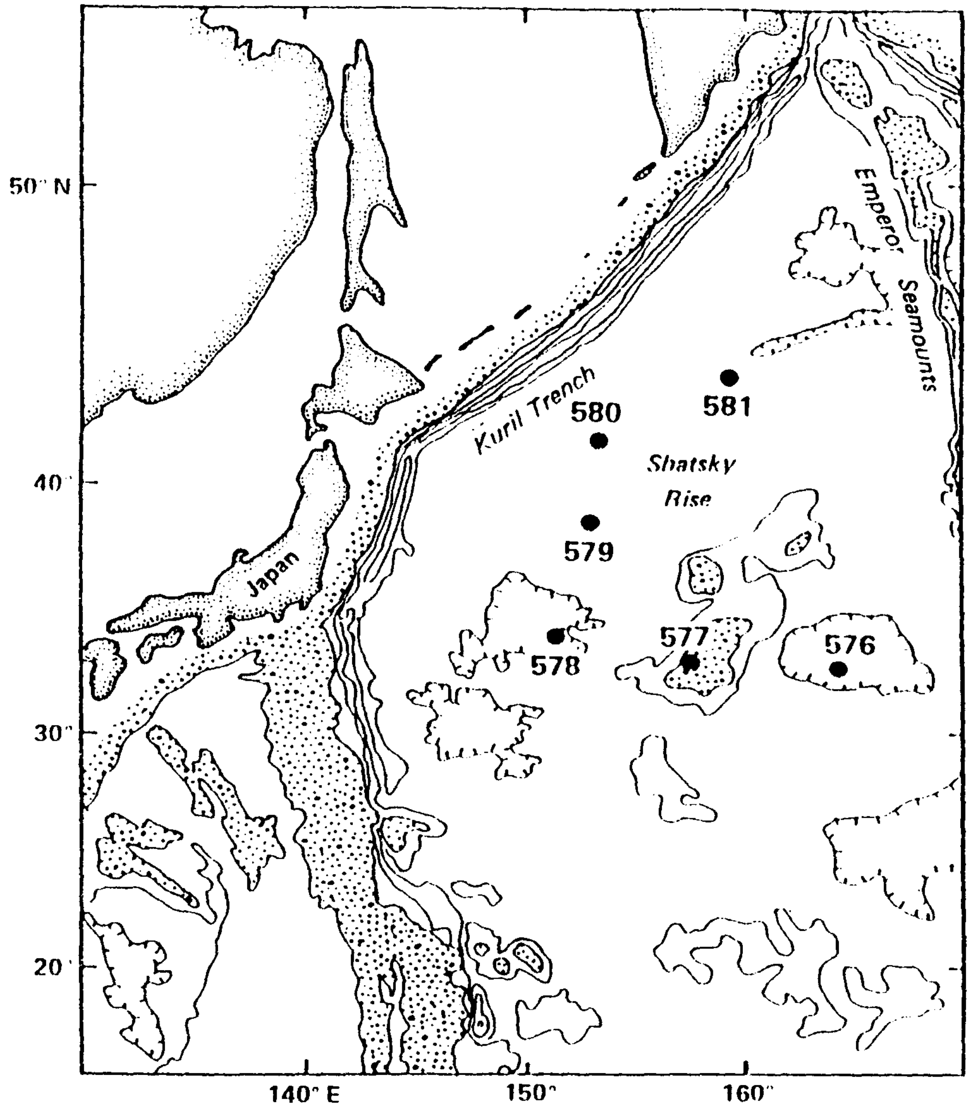


Figure 3. Map depicting location of Site 580 relative to the Japanese and Sakhalin Islands, and the Kuril-Kamchatka Trench. From Heath, Burckle et al., (1985).

Sakhalin Range

The Cenozoic strata on Sakhalin Island are very similar to those on Kamchatka. For this reason interpreting temporal changes in qualitative IRD abundance and composition at Site 580 may be difficult. Sakhalin is due west of Site 580 and may have been glaciated repeatedly during the Pleistocene and periods of Northern Hemisphere cooling. Whether increased IRD deposition increased at Site 580 because of southward migration of the subarctic front, or whether it was due to increased glaciation on Sakhalin Island is not obvious. However, Kamchatka is geographically much larger than Sakhalin and so even though it is a greater distance from Site 580, I will consider it as the most likely source of IRD. Therefore, increasing accumulation of carbonate IRD will be interpreted to represent extreme southward expansion of the warm/cold water interface.

Below is a list of predominant lithologies in each geographic region :

Source Stratigraphy. From Nalivkin, (1973).	
Eastern Kamchatka	Basalt, quartzite, minor sandstone.
Western Kamchatka	Interbedded Cenozoic conglomerates, sandstones, carbonates, and shales (D'yakov, 1956). Marble, quartzite, and slate increase to center of island.
Okhotsk Coast	Granitic, quartz sand.

Source Stratigraphy. From Nalivkin, (1973).	
N. Siberian Coast	Basalt, quartzite, minor sedimentary rock.
Kuril Islands	Andesite, tuffaceous breccia, sandstone. (Nikol'ski, 1959).
Sakhalin Islands	Andesite, basalt, Cenozoic sedimentary including carbonate.

Procedure

Preparation

Core sediments were originally analyzed by the shipboard scientific party of Leg 86, DSDP, in 1982. These samples have been supplied to me by Lawrence A. Krissek Ph.D. for continued analysis. All samples previously had been washed and filtered to isolate the 250 m to 2.0 mm coarse fraction. This range of grain sizes is also referred to as the coarse fraction and was initially used to give a rough estimate of IRD abundance and accumulation rate (Krissek, et al., 1985).

Analytical Procedure

Sample analysis was conducted with a binocular microscope and picking tray. My intent was not to identify exact grain composition, but rather to describe each IRD grain's general lithology in order to determine most likely location of origin. Having done a point count of each type of IRD grain lithology I have assimilated the data on a spreadsheet and created volumetric abundance graphs and mass accumulation rate graphs. These graphs reveal temporal fluctuations in IRD composition. Lithologic changes are then inferred to represent changes in paleocurrent intensity and location and possibly IRD source area as well. Mass accumulation rate (MAR) values were calculated to give an account of relative lithology importance by:

$$MAR = X\%_{cf} X\%_{IRD} X\%_{lithl} . Sed.Rate [\rho_{drybulk}]$$

$X\%_{cf}$ = percent of total sediment in coarse fraction (250 m to 2mm).
$X\%_{IRD}$ = percent IRD of coarse fraction.
$X\%_{lithl}$ = percent specific lithology of total IRD population.
Sed. Rate = Sedimentation rate. Taken to be 5000 cm/My.
$\rho_{dry\ bulk}$ = Dry bulk density of specific lithology. See data tables.

Dry bulk density values were obtained from values calculated by Schultheiss (1985). Sedimentation rate is taken as a constant of 5000 centimeters per one million years which was calculated by Heath, Burckle, et al., (1985),(Figure 4). These mass accumulation rate values are then plotted against time to reveal temporal variations in qualitative chemical composition.

Relative percent composition for the various IRD components was calculated by counting individual grain types in a given sample, estimating mean grain diameter:

$$Volume = \frac{4}{3} \pi \left[\frac{D}{2} \right]^2$$

D = average lithology grain diameter in sample.

Volume percentage values were calculated with the following equation:

$$Volume\% = \frac{Volume_a}{V_a + V_b + V_c + \ldots}$$

Volume$_a$ = Sample cumulative lithology grain volume.
V_a+V_b+... = Total sample IRD grain volume.

Percentages are reported in both volumetric (body) and mass weighted values (appendix). Mass weighted values are calculated with the following:

$$Mass\% = \frac{[Volume_a]\,[Density_a]}{V_a D_a + V_b D_b + V_c D_c + \ldots}$$

Volume$_a$ = Sample cumulative lithology grain volume.
Density$_a$ = Lithology specific density. See data tables.
V_aD_a+V_bD_b+V_cD_c+... = Cumulative sample IRD mass.

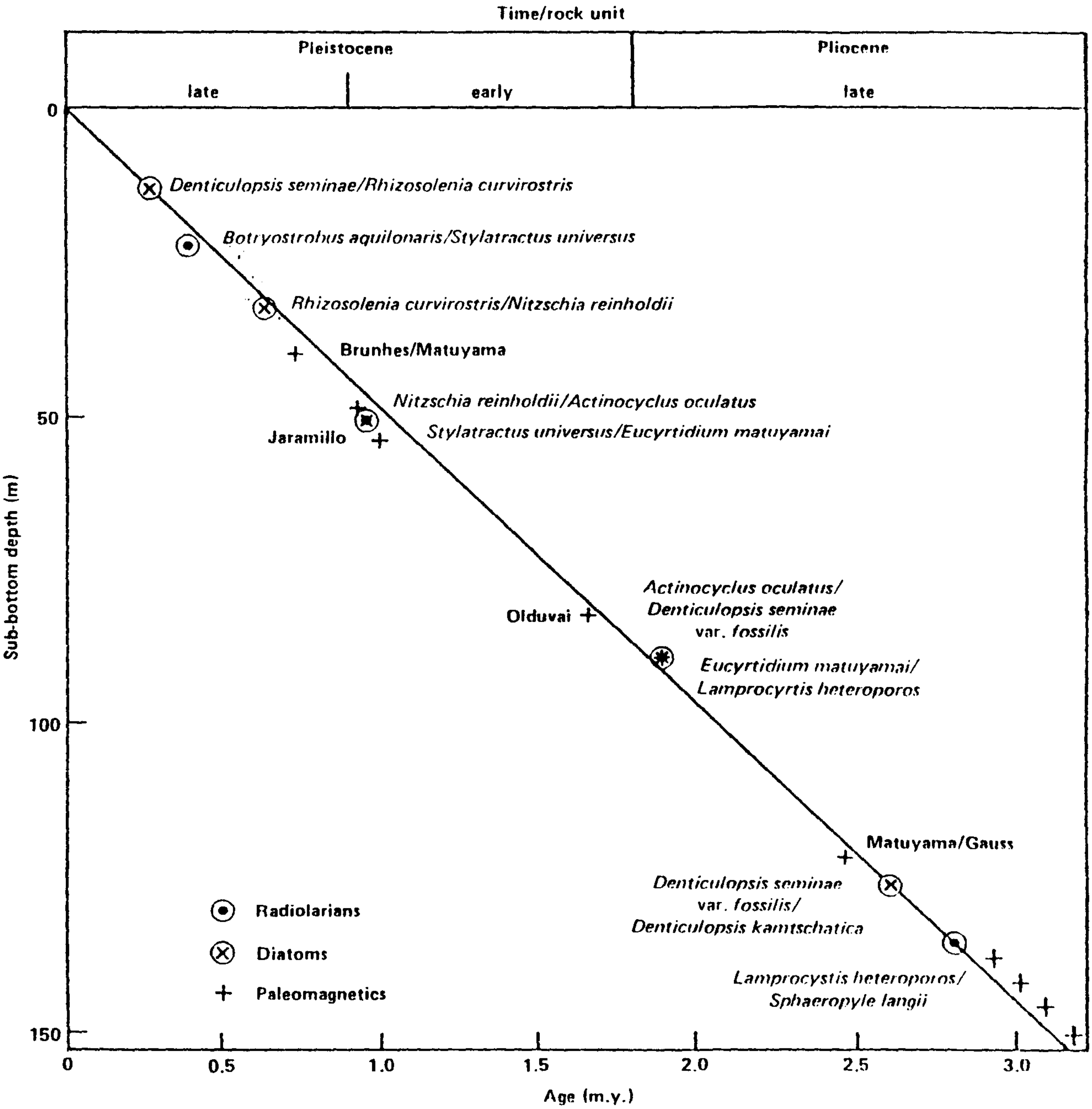


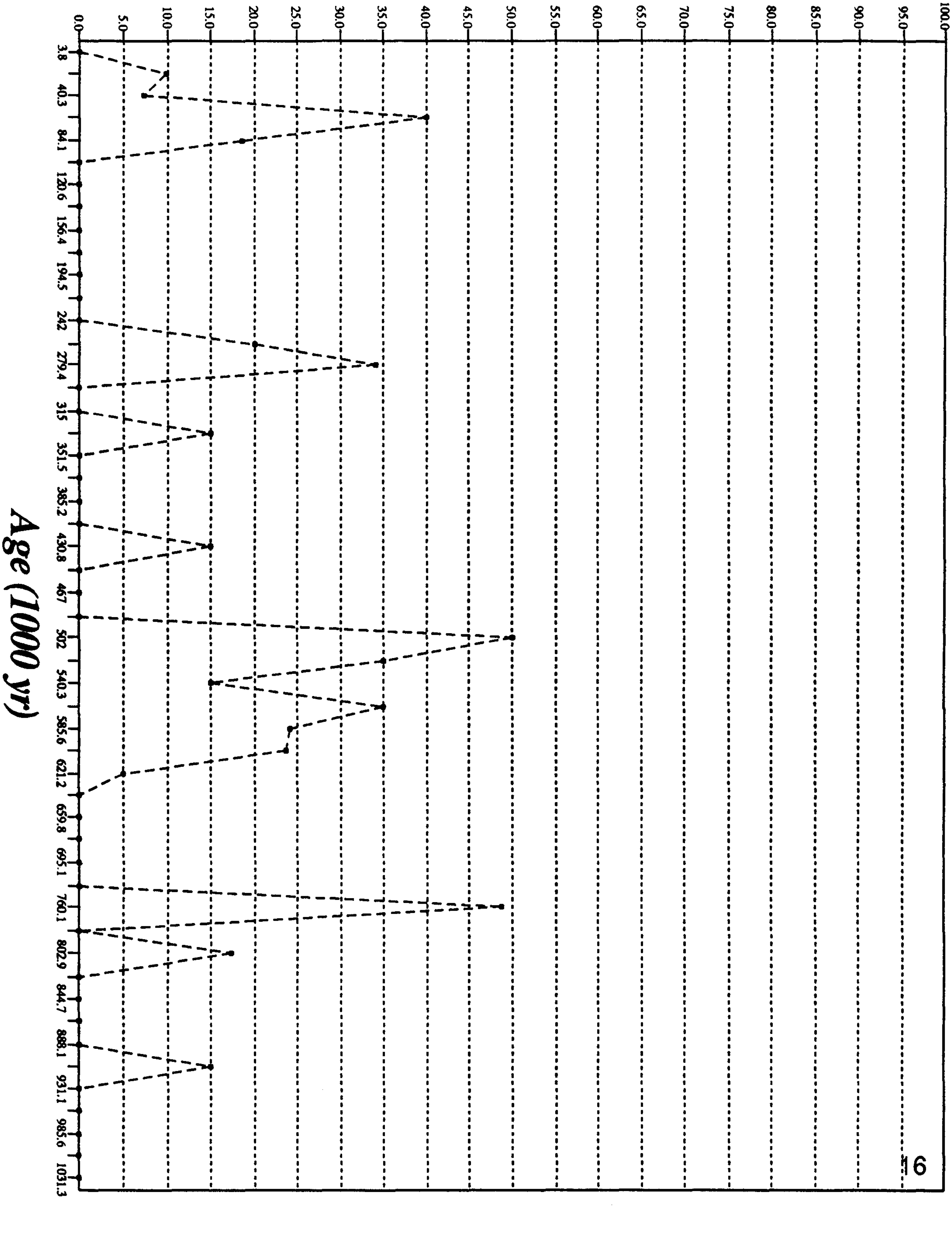
Figure 4. Diagram from Heath, Burckle, et al., (1985) depicting Sedimentation Rate.

Analysis IRD from Site 580 Deep Sea Drilling Project : North Pacific
Mass Accumulation Rate Data:

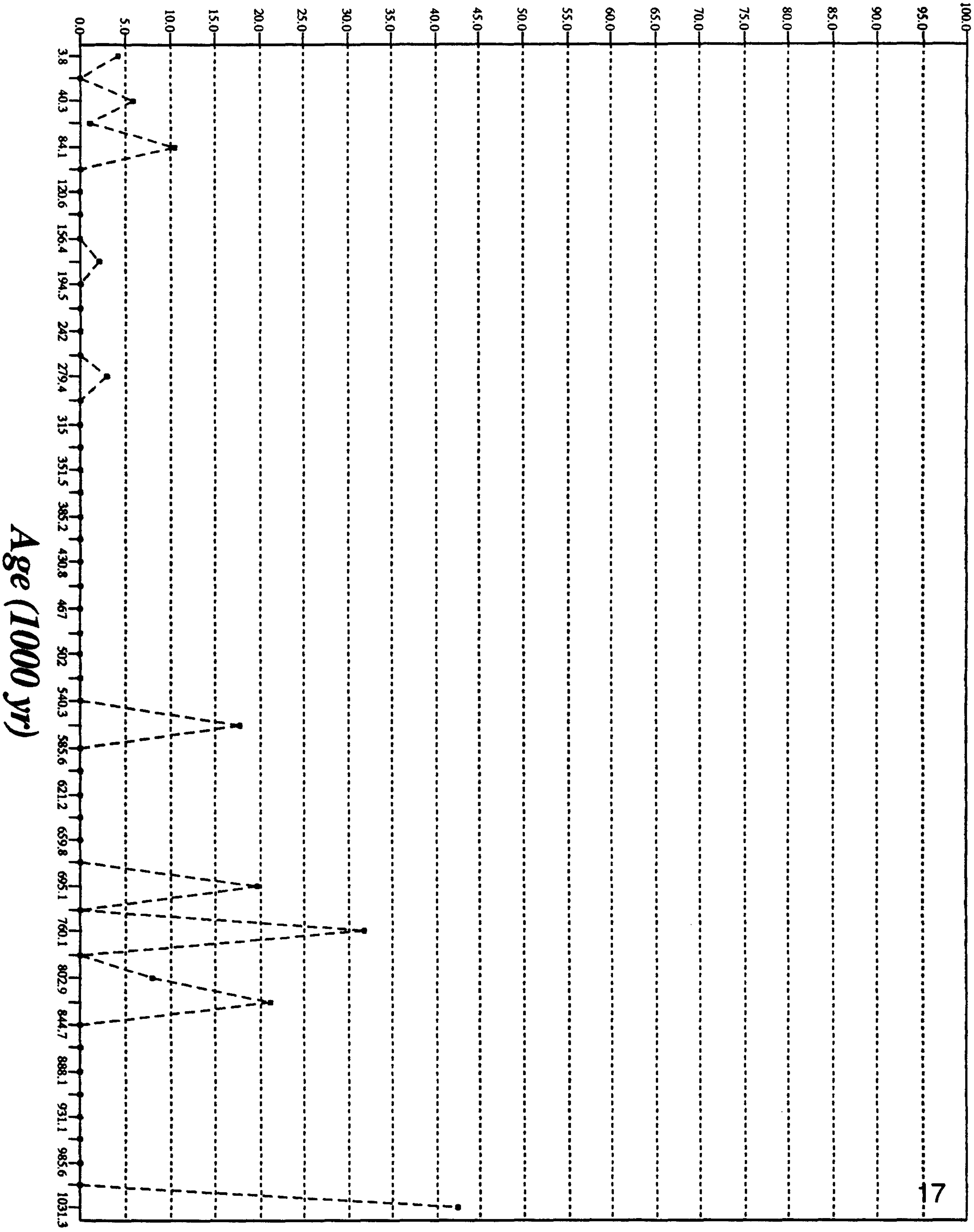
Sample	AGE	C.F. %	IRD %	Quartz	Qtzite	Carbon	Peridote	B Mafic	Granitic	Siltstn	Remarks:
1-1, 20	3.8	0.0012	7.5	80	4	0	0	0	4	0	
1-1,120	22.1	0.0102	21.5	37.8	0	15.1	6	9.7	0	30.8	Rhyolite\Chert
1-2,70	40.3	0.0035	26	58.8	26.4	0	2.9	7.3	5.8	1.5	Gabbro
2-1,32	66.2	0.0118	7	60	0	0	0	40	1	0	
2-1,130	84.1	0.0069	50	42.2	10	0	18.5	18.5	10.6	0	Chert
2-2,80	102.4	0.0014	10	52	18.75	4.2	20.8	0	0	2.08	Limonite
2-3,30	120.6	0.0002	4.6	90	5	2.5	2.5	0	0	0	
2-3,130	138.9	0.0002	0	0	0	0	0	0	0	0	
2-4,76	156.4	0.0039	75	75	6	4	15	0	0	0	
2-5,30	175.4	0.0093	43	65	17	5	15	0	2	0	Chert
2-5,135	194.5	0.0026	32.5	59	23	0	15	0	0	0	
2-6,40	204.6	0.0024	30.5	60	10	0	6.5	0	0	0	
3-1,45	242	0.0001	2	66	33	0	0	0	0	0	
3-1,145	260.2	0.0012	14.7	42	28	0	9.7	20	0	0	
3-2,100	279.4	0.003	22.5	39.5	3.9	8	11.7	34	2.9	0	
3-3,45	296.7	0.003	15.5	52.2	30	3	5.8	0	0	0	
3-3,145	315	0.0103	25	36.5	48.7	0	14.6	0	0	0	
3-4,80	330.5	0.0013	3	38	15	20	10	15	0	0	
3-5,45	351.5	0.0004	0	0	0	0	0	0	0	0	
3-5,110	363.3	0.0058	25.4	65	25	0	10	0	0	0	
3-6,80	385.2	0.0002	3.8	100	0	0	0	0	0	0	
4-1,28	412.2	0.0065	1.2	0	0	0	0	0	0	0	
4-1,130	430.8	0.0026	28.1	77	0	3	5	15	0	0	Chert
4-2,70	447.3	0.0009	9.1	50	0	25	0	0	0	25	
4-3,28	467	0.0011	49.6	60	0	10	10	0	0	20	
4-3,130	485.6	0	5.6	0	0	0	0	0	0	0	
4-4,70	502	0.0007	2.5	25	25	0	0	50	0	0	
4-5,28	521.7	0.0005	34.8	20	45	0	0	35	0	0	
4-5,130	540.3	0.0003	80.9	61.5	11.7	0	11.7	15	0	0	
4-6,74	557.5	0.0003	13.4	47	0	0	0	35	17.6	0	
5-1,28	585.6	0.0003	37	45.4	0	0	18.1	24.2	0	12.1	
5-1,135	605.1	0.0015	35	64	0	0	0	23.7	0	12.1	
5-2,70	621.2	0.0007	58.8	60	25	0	5	5	0	0	
5-3,28	640.3	0.0007	47.7	43	31	26	0	0	0	0	Muscovite
5-3,135	659.8	0.0002	6.2	50	0	0	50	0	0	0	
5-4,83	677.7	0.0048	51	100	0	0	0	0	0	0	
5-5,28	695.1	0	25	36.6	19.5	24.3	0	0	19.5	0	
5-5,110	710	0.0017	2.9	0	0	0	0	0	0	0	
6-1,9	760.1	0.0033	15.3	0	0	0	0	48.7	31.7	19.5	
6-1,106	780.6	0.0017	3.8	29.4	35.2	0	0	0	0	35.2	
6-2,60	802.9	0.005	78.8	49.8	0	23.2	1.6	17.4	8	0	
6-3,9	824	0.0011	32	55.5	0	0	0	0	21.2	23.1	
6-3,106	844.7	0.0007	2.4	0	0	0	100	0	0	0	Shale
6-4,52	865.3	0.0004	2.9	0	50	0	0	0	0	50	
6-5,9	888.1	0.0055	0	0	0	0	0	0	0	0	
6-5,106	908.8	0.0012	7	60	0	25	0	15	0	0	
6-6,60	931.1	0	0	0	0	0	0	0	0	0	Lost
7-1,13	963.8	0.0015	4.4	76.2	0	0	0	0	0	23.8	
7-1,115	985.6	0.0015	50.6	80	5	0	15	0	0	0	
7-2,86	1011.4	0.0013	3.3	100	0	0	0	0	0	0	
7-3,29	1031.3	0.0008	50	0	0	51.1	0	0	42.2	6.6	

CF% = Coarse-Sand Fraction (Weight %) AGE = decreased by factor E+3
IRD% = IRD weight %. Lithology columns = volume % of total IRD.

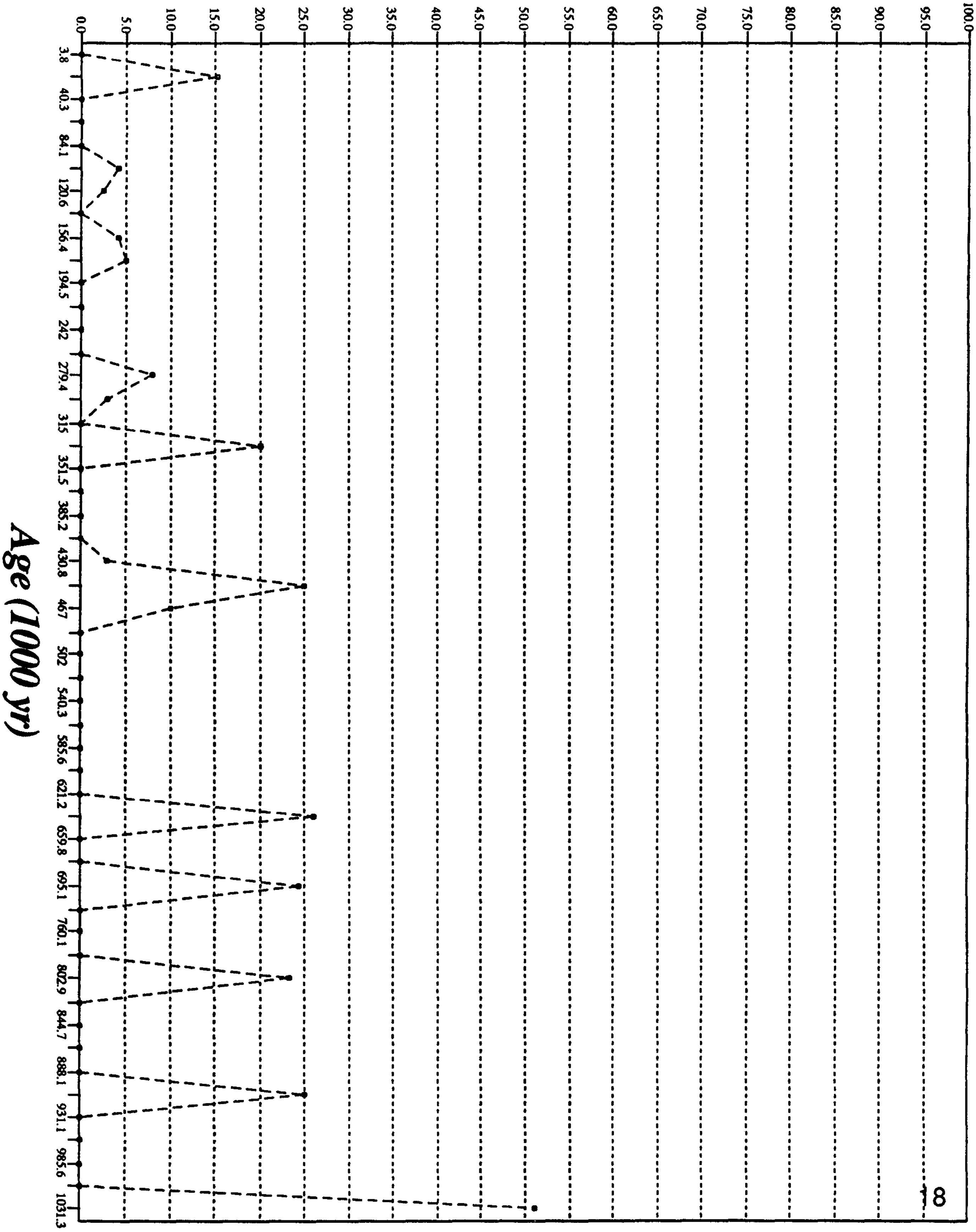
Percent Black Mafic



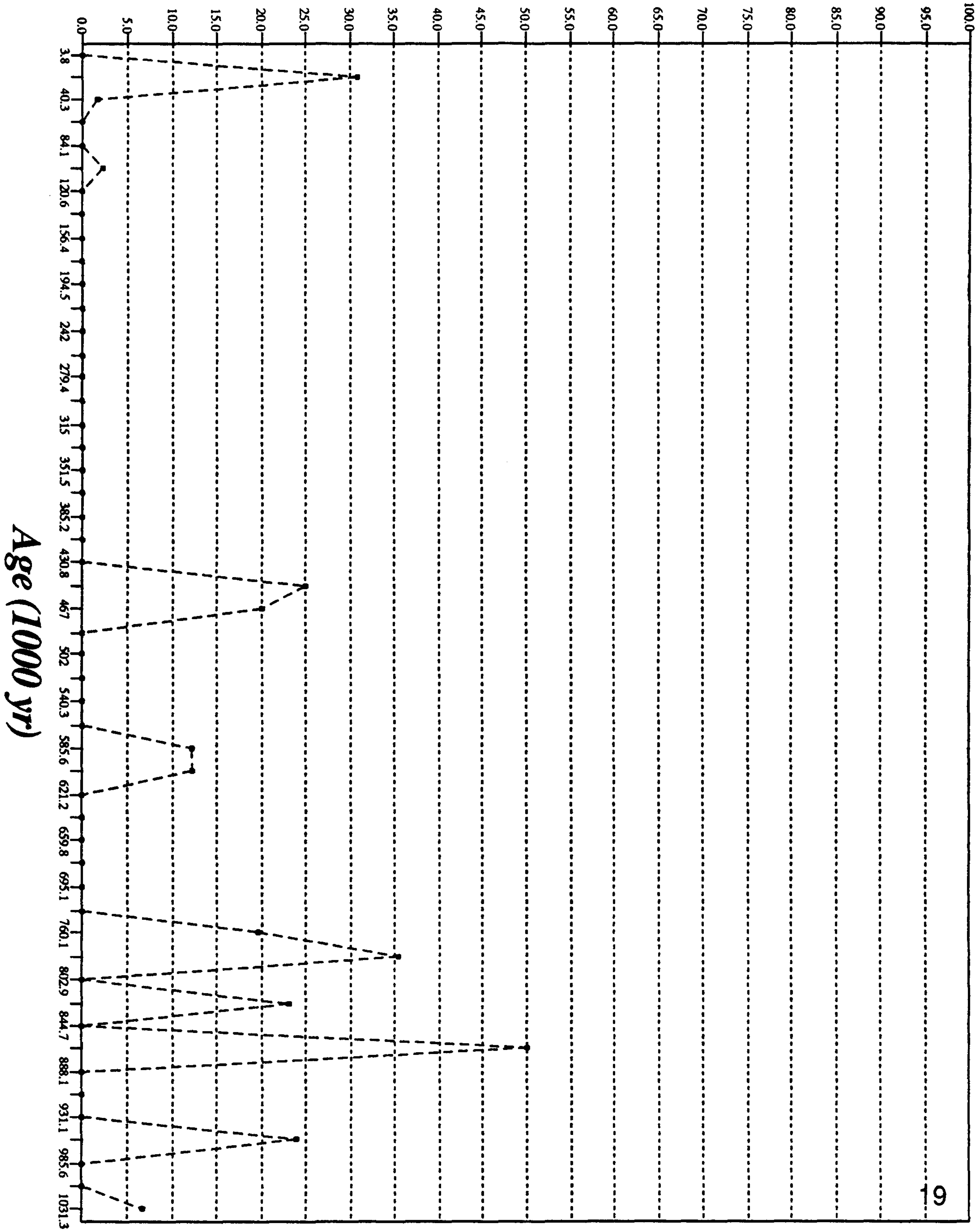
Percent Granite

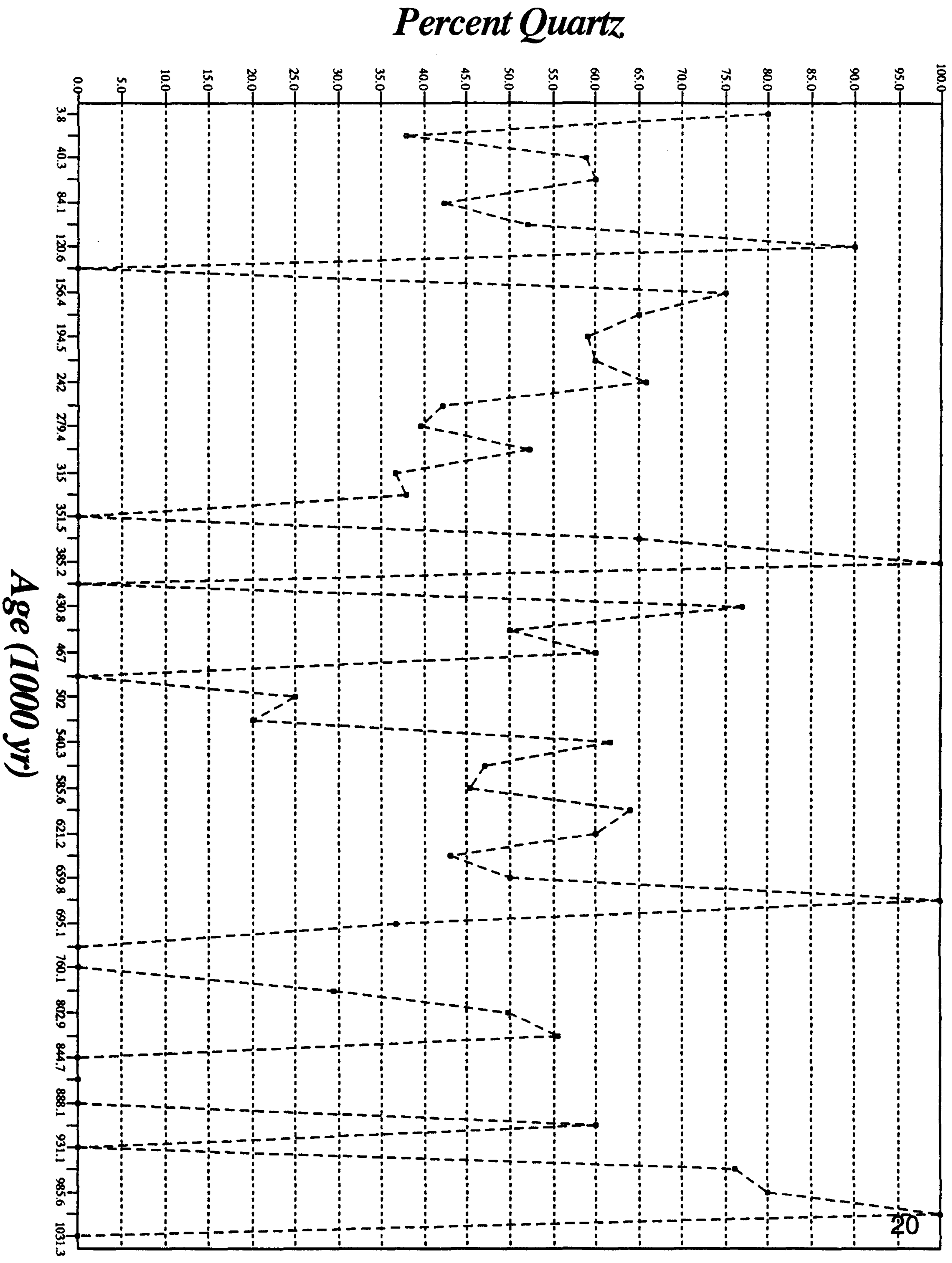


Percent Carbonate

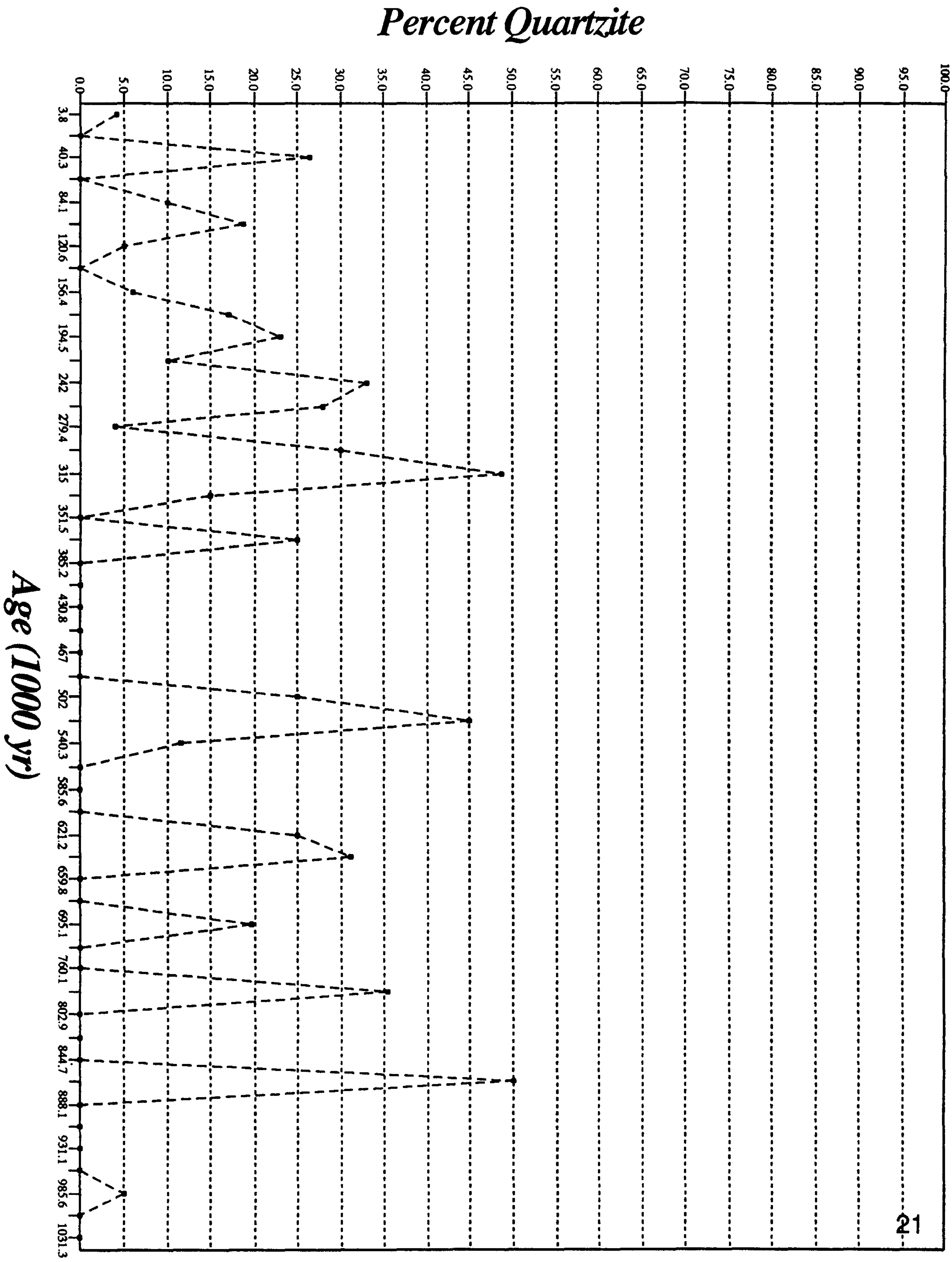


Percent Lithics





Percent Quartz
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
55.0
60.0
65.0
70.0
75.0
80.0
85.0
90.0
95.0
100.0
3.8
40.3
84.1
120.6
156.4
194.5
242
279.4
315
351.5
385.2
430.8
467
502
540.3
585.6
621.2
659.8
695.1
760.1
802.9
844.7
888.1
931.1
985.6
1031.3
Age (1000 yr)


Percent Quartzite
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70.0
75.0
80.0
85.0
90.0
95.0
100.0
3.8
40.3
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156.4
194.5
242
279.4
315
351.5
385.2
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621.2
659.8
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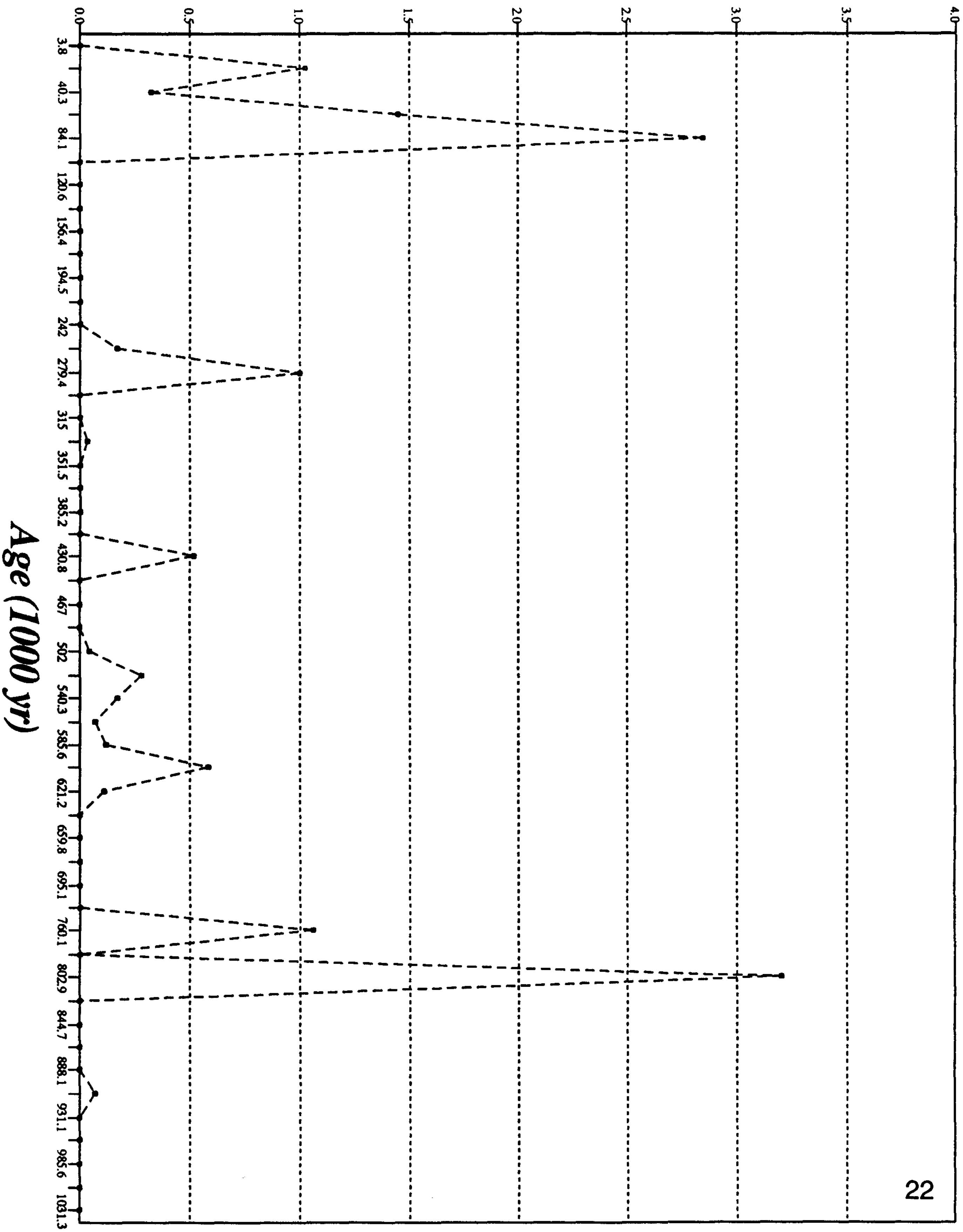
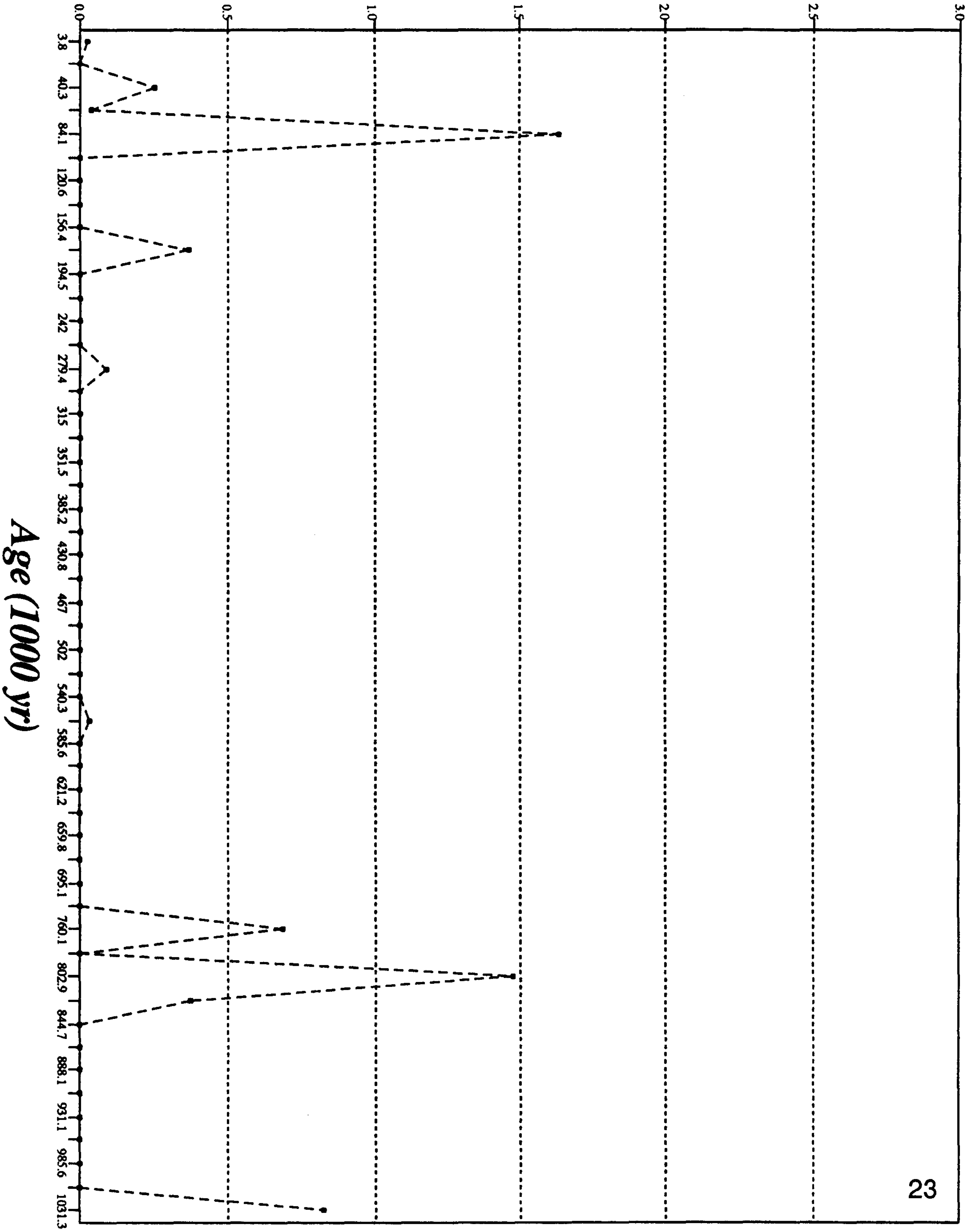
931.1
985.6
1031.3
Age (1000 yr)

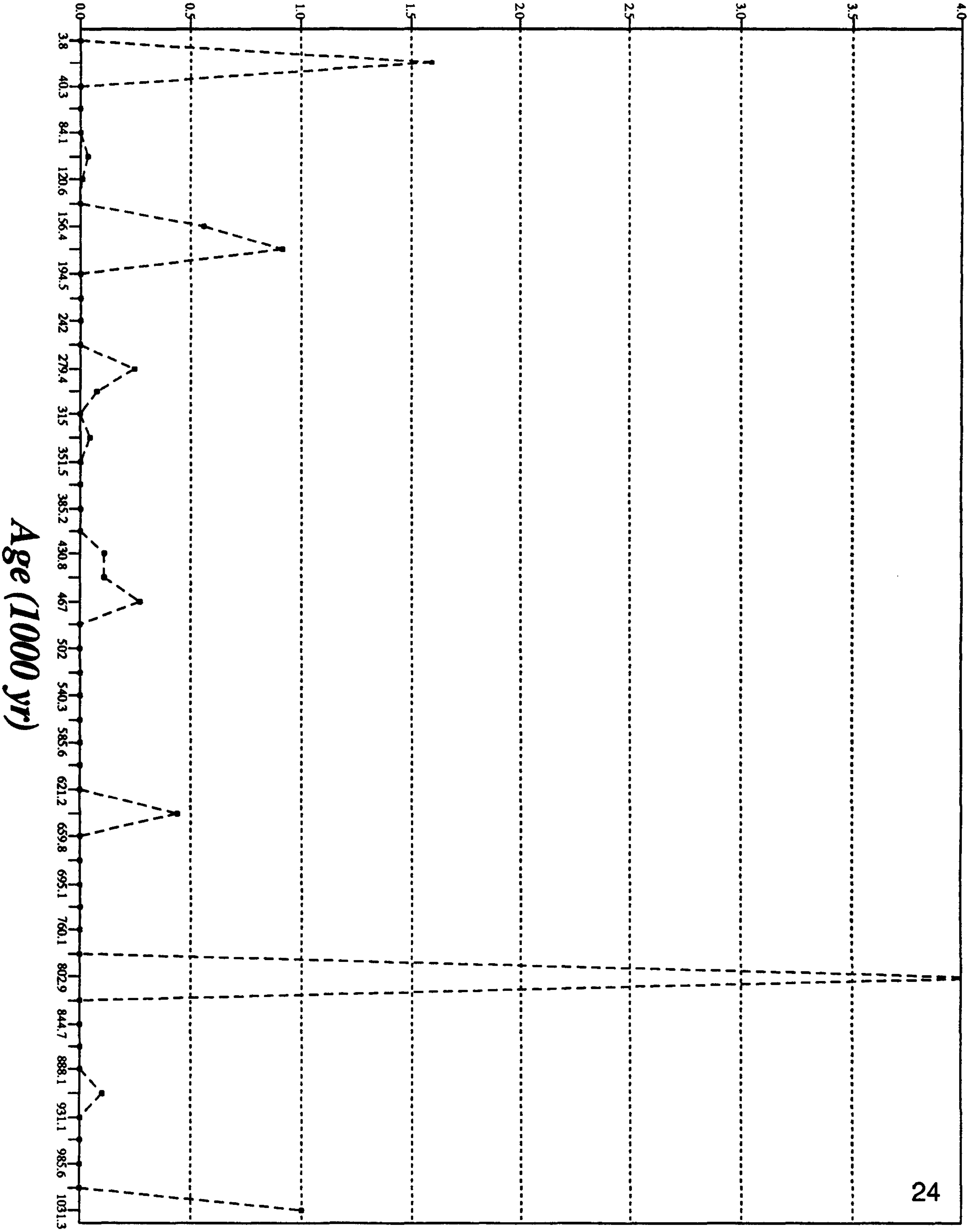
Mass Accumulation Rate Black Mafic



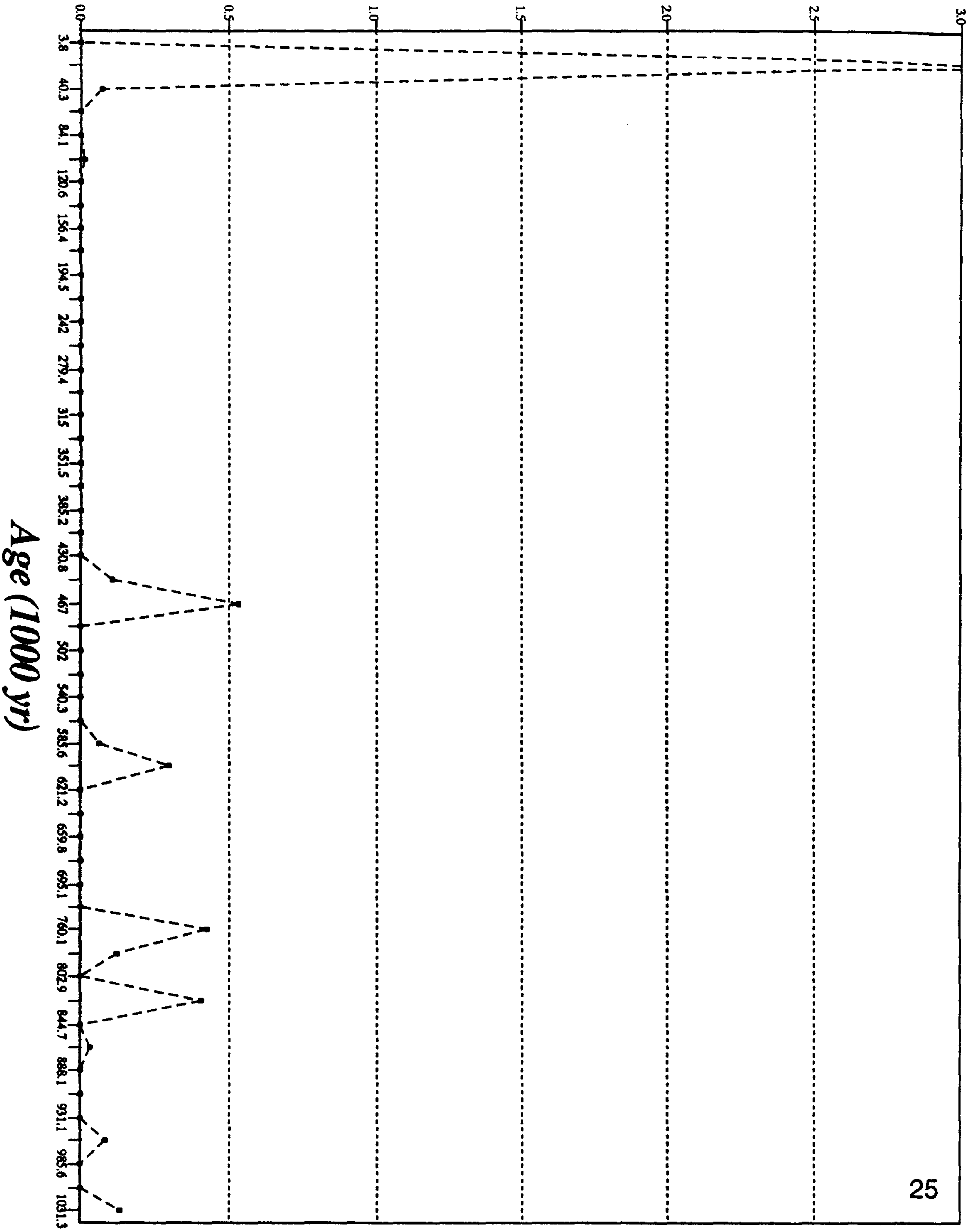
Mass Accumulation Rate Granite



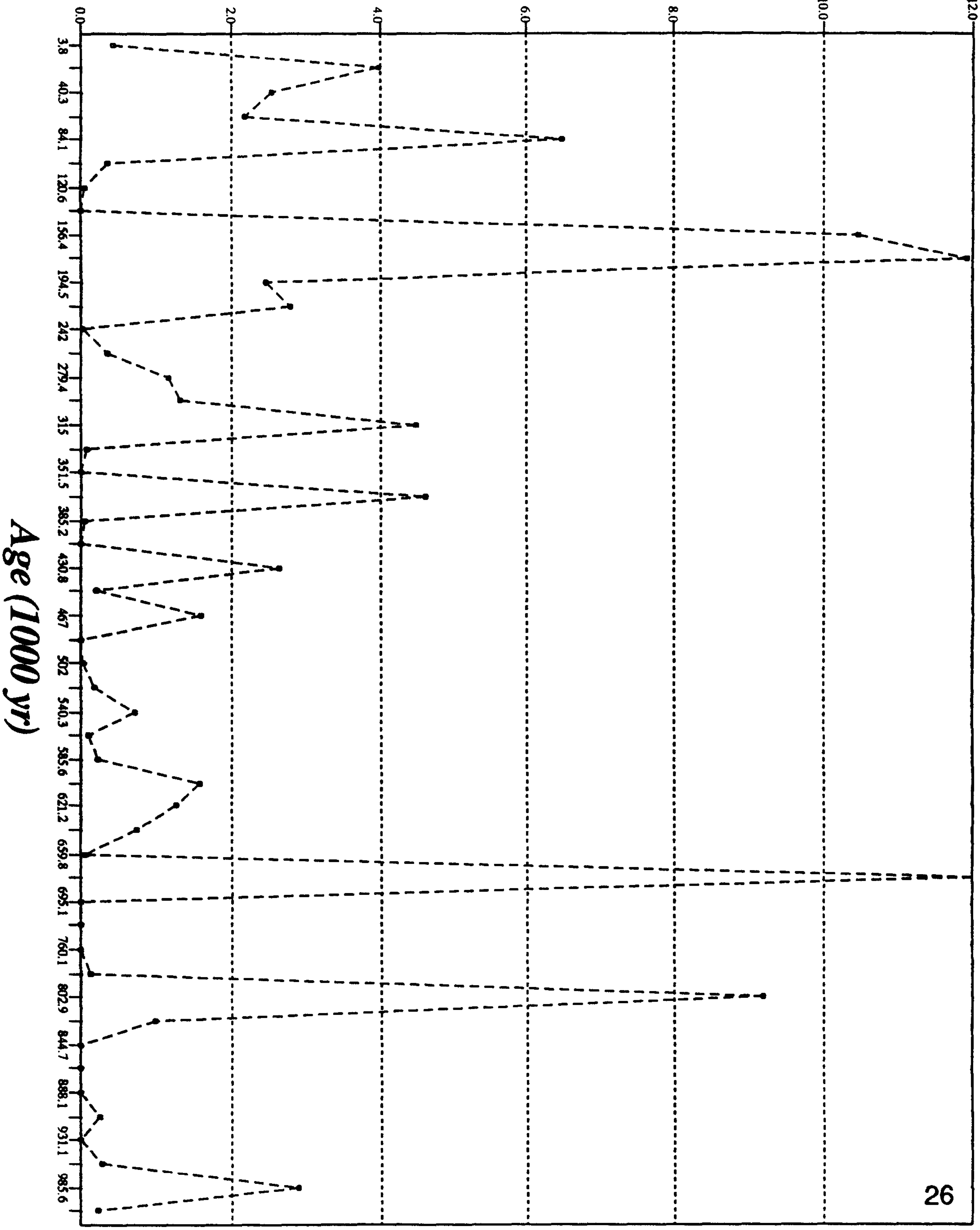
Mass Accumulation Rate Carbonate



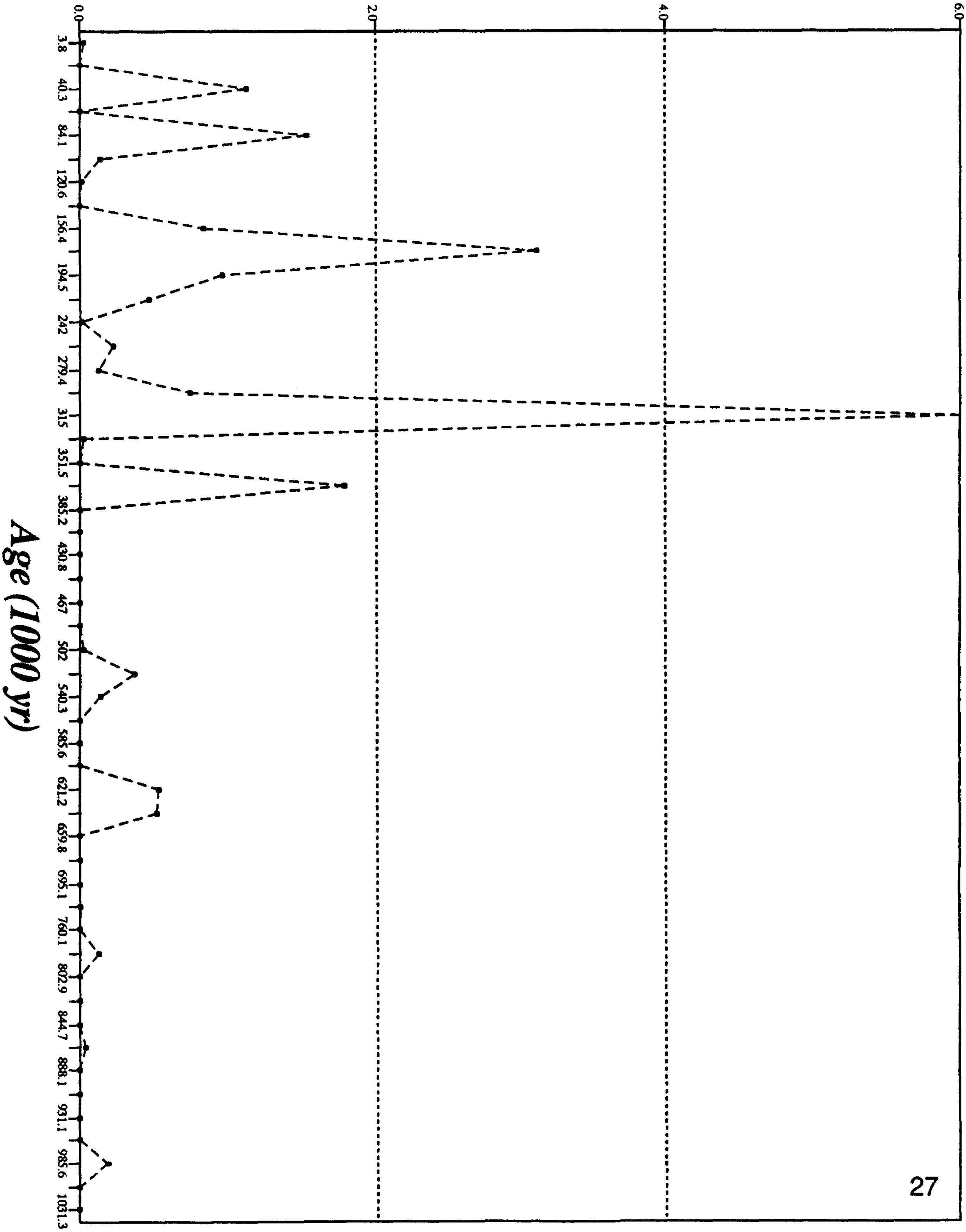
Mass Accumulation Rate Lithics

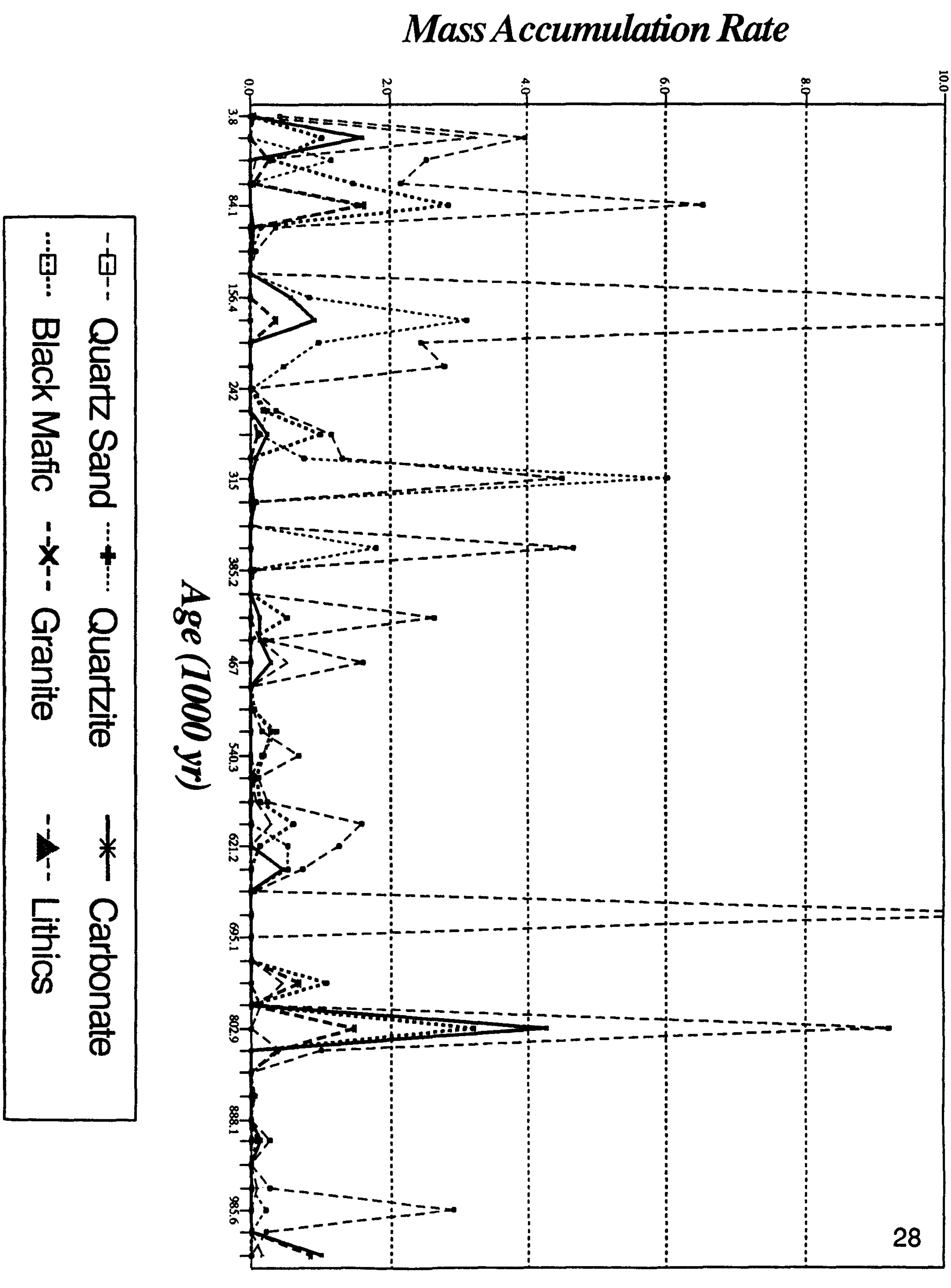


Mass Accumulation Rate Quartz



Mass Accumulation Rate Quartzite




Mass Accumulation Rate
0.0
2.0
4.0
6.0
8.0
10.0
3.8
84.1
156.4
242
315
385.2
467
540.3
621.2
695.1
802.9
888.1
985.6
Age (1000 yr)
Quartz Sand
Quartzite
Carbonate
Black Mafic
Granite
Lithics

DISCUSSION OF FINDINGS

Figure 18 depicts the combined mass accumulation rate graphs for each lithology of ice rafted debris present. While the relative MAR of each constituent is somewhat constant there are a few irregular populations worth further analysis.

Mass accumulation rate peaks at 22.1, 84.1, and 156.4 to 204.4 thousand years ago are all comprised of roughly the same relative values for each component. These peaks show the effects of general global cooling along with increased glaciation, calving, and IRD deposition. The IRD did not originate from any one lithologically distinct location. Likewise, the average MAR values reveal that the subarctic front was not in a position to facilitate IRD deposition from any single geographic location. The subarctic front must have been sufficiently far south of the Kamchatka Peninsula to allow icebergs to migrate out of the Sea of Okhotsk and drift southward to Site 580. Peaks at 22.1, 84.1, and 156.4 to 204.4 thousand years ago each represent an intense period of IRD deposition and do not lend themselves to separation.

MAR peaks occur again at 315 and 363.3 thousand years ago. These periods are denoted by a high rate of deposition of quartz sand, quartzite, and peridote. This combination of grains would most likely originate on Western Kamchatka or Sakhalin Island. The absence of black mafic grains eliminates Eastern Kamchatka, N. Siberia, and the Kuril Islands while the absence of granitic fragments eliminates the shore of the Sea of Okhotsk. Sakhalin Island origination would denote intense glaciation and northern migration of the subarctic front. IRD from Western Kamchatka could represent the subarctic front in its present location combined with an increase in iceberg calving in the Sea of Okhotsk.

Quartz sand is the major component of IRD deposition occurring 677.7 thousand years ago. This is surprising due to the relatively high percentage of IRD present within the coarse fraction. Virtually all grains have been extensively weathered, as inferred from the high degree of rounding. I counted 42 quartz sand grains whose mean diameter was approximately .25 mm. There is very little variance in grain size or appearance and only other lithology present is represented by three grains of peridot.

All components except quartzite are present at the final peak occurring at 802.9 thousand years ago. The absence of quartzite is surprising and is possibly due to origination on the Kuril and Sakhalin Islands. These areas are seemingly lacking in significant presence of quartzite rock.

Conclusions

Qualitative analysis of these samples has been conducted and the data gained is reliable. However I have had a few problems in reaching conclusions as to the meaning of the data.

First of all, many of the IRD peaks are represented by a single grain of the specific lithology. This is especially common as core depth increases. Many of these grains are large and distinct, but they are still the only representative of that lithology in that sample. This can lead to artificially high weighting in terms of mass accumulation rate, and, therefore, to faulty conclusions. This occurs quite often for all grains except quartz sand. I have enclosed grain count data as an appendix so the reader can also observe this single sample population occurrence and consider it's significance.

The only other problem I have encountered in interpreting this data is the large interval between samples. Average sample interval is twenty thousand years and this does not allow for good resolution of paleoclimatic variation (Carney, 1986).

Despite the above considerations it is reasonable to assume that qualitative variations in IRD composition represent either changing source area, variations in paleocurrents, or perhaps both.

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Appendix

Analysis IRD from Site 580 Deep Sea Drilling Proj Black Mafic Data

Black Mafic Density = .004 g/mm^3 Sed Rate (cm/My) = 5000

Sample	% BM	NO.	Mean Diameter	Volume	Total Volume	Mass (grams)	MAR
1-1, 20	0	0	0	0	0	0	0
1-1,120	9.7	6	0.6	0.113	0.6782	0.0027	1.0208
1-2,70	7.3	2	0.4	0.0335	0.067	0.0003	0.3129
2-1,32	40	4	1	0.5233	2.0933	0.0084	1.4508
2-1,130	18.5	5	0.4	0.0335	0.1675	0.0007	2.8476
2-2,80	0	0	0	0	0	0	0
2-3,30	0	0	0	0	0	0	0
2-3,130	0	0	0	0	0	0	0
2-4,76	0	0	0	0	0	0	0
2-5,30	0	0	0	0	0	0	0
2-5,135	0	0	0	0	0	0	0
2-6,40	0	0	0	0	0	0	0
3-1,45	0	0	0	0	0	0	0
3-1,145	20	2	0.5	0.0654	0.1308	0.0005	0.1615
3-2,100	34	2	1.5	1.7663	3.5325	0.0141	0.9983
3-3,45	0	0	0	0	0	0	0
3-3,145	0	0	0	0	0	0	0
3-4,80	15	1	1	0.5233	0.5233	0.0021	0.0275
3-5,45	0	0	0	0	0	0	0
3-5,110	0	0	0	0	0	0	0
3-6,80	0	0	0	0	0	0	0
4-1,28	100	1	0.6	0.113	0.113	0.0005	0
4-1,130	15	1	0.3	0.0141	0.0141	5.7E-05	0.5146
4-2,70	0	0	0	0	0	0	0
4-3,28	0	0	0	0	0	0	0
4-3,130	0	0	0	0	0	0	0
4-4,70	50	2	0.3	0.0141	0.0283	0.0001	0.0377
4-5,28	35	1	0.8	0.2679	0.2679	0.0011	0.2738
4-5,130	15	6	0.5	0.0654	0.3925	0.0016	0.1678
4-6,74	35	2	0.75	0.2208	0.4416	0.0018	0.0631
5-1,28	24.2	2	1	0.5233	1.0467	0.0042	0.1187
5-1,135	23.7	5	0.75	0.2208	1.1039	0.0044	0.5805
5-2,70	5	1	0.4	0.0335	0.0335	0.0001	0.1048
5-3,28	4	1	0.3	0.0141	0.0141	5.7E-05	0
5-3,135	0	0	0	0	0	0	0
5-4,83	0	0	0	0	0	0	0
5-5,28	0	0	0	0	0	0	0
5-5,110	0	0	0	0	0	0	0
6-1,9	48.7	1	2	4.1867	4.1867	0.0167	1.0567
6-1,106	0	0	0	0	0	0	0
6-2,60	17.4	7	0.6	0.113	0.7913	0.0032	3.2059
6-3,9	0	0	0	0	0	0	0
6-3,106	0	0	0	0	0	0	0
6-4,52	0	0	0	0	0	0	0
6-5,9	0	0	0	0	0	0	0
6-5,106	15	1	0.3	0.0141	0.0141	5.7E-05	0.0598
6-6,60	0	0	0	0	0	0	0
7-1,13	0	0	0	0	0	0	0
7-1,115	0	0	0	0	0	0	0
7-2,86	0	0	0	0	0	0	0
7-3,29	0	0	0	0	0	0	0

Analysis IRD from Site 580 Deep Sea Drilling Project : Granite Data
Granite IRD: Mass = .0032 g/mm^3 Sed. Rate (cm/my 5000

Sample	% Gran	NO.	Mean Diameter	Volume	Total Volume	Mass (grams)	MAR
1-1, 20	4	2	0.4	0.0335	0.067	0.0002	0.0204
1-1,120	0	0	0	0	0	0	0
1-2,70	5.8	1	0.3	0.0141	0.0141	4.5E-05	0.2486
2-1,32	1	1	0.75	0.2208	0.2208	0.0007	0.0363
2-1,130	10.6	2	0.5	0.0654	0.1308	0.0004	1.6316
2-2,80	0	0	0	0	0	0	0
2-3,30	0	0	0	0	0	0	0
2-3,130	0	0	0	0	0	0	0
2-4,76	0	0	0	0	0	0	0
2-5,30	2	2	0.4	0.0335	0.067	0.0002	0.3669
2-5,135	0	0	0	0	0	0	0
2-6,40	0	0	0	0	0	0	0
3-1,45	0	0	0	0	0	0	0
3-1,145	0	0	0	0	0	0	0
3-2,100	2.9	1	0.6	0.113	0.113	0.0004	0.0851
3-3,45	0	0	0	0	0	0	0
3-3,145	0	0	0	0	0	0	0
3-4,80	0	0	0	0	0	0	0
3-5,45	0	0	0	0	0	0	0
3-5,110	0	0	0	0	0	0	0
3-6,80	0	0	0	0	0	0	0
4-1,28	0	0	0	0	0	0	0
4-1,130	0	0	0	0	0	0	0
4-2,70	0	0	0	0	0	0	0
4-3,28	0	0	0	0	0	0	0
4-3,130	0	0	0	0	0	0	0
4-4,70	0	0	0	0	0	0	0
4-5,28	0	0	0	0	0	0	0
4-5,130	0	0	0	0	0	0	0
4-6,74	17.6	1	0.75	0.2208	0.2208	0.0007	0.0317
5-1,28	0	0	0	0	0	0	0
5-1,135	0	0	0	0	0	0	0
5-2,70	0	0	0	0	0	0	0
5-3,28				0	0	0	0
5-3,135	0	0	0	0	0	0	0
5-4,83	0	0	0	0	0	0	0
5-5,28	19.5	1	0.4	0.0335	0.0335	0.0001	0
5-5,110	0	0	0	0	0	0	0
6-1,9	31.7	1	1.5	1.7663	1.7663	0.0057	0.6878
6-1,106	0	0	0	0	0	0	0
6-2,60	8	4	0.4	0.0335	0.134	0.0004	1.474
6-3,9	21.2	1	2	4.1867	4.1867	0.0134	0.3725
6-3,106	0	0	0	0	0	0	0
6-4,52	0	0	0	0	0	0	0
6-5,9	0	0	0	0	0	0	0
6-5,106	0	0	0	0	0	0	0
6-6,60	0	0	0	0	0	0	0
7-1,13	0	0	0	0	0	0	0
7-1,115	0	0	0	0	0	0	0
7-2,86	0	0	0	0	0	0	0
7-3,29	42.2	1	1.5	1.7663	1.7663	0.0057	0.8232

NO. = Number of granite grains MAR = grams/cm^2/My
Volume = mm^3 Diameter is in mm.

Analysis IRD from Site 580 Deep Sea Drilling Project : Carbonate Data
Carbonate IRD Mass Accumulation Data G=2.71 Sed Rate (cm/my 5000

Sample	% Carb'	NO.	Mean Diameter	Volume	Total Volume	Mass	MAR
1-1, 20	0	0	0	0	0	0	0
1-1,120	0.151	4	1.5	1.7663	7.065	0.0191	1.589
1-2,70	0	0	0	0	0	0	0
2-1,32	0	0	0	0	0	0	0
2-1,130	0	0	0	0	0	0	0
2-2,80	0.042	2	0.5	0.0654	0.1308	0.0004	0.0281
2-3,30	0.025	1	0.7	0.1795	0.1795	0.0005	0.0011
2-3,130	0	0	0	0	0	0	0
2-4,76	0.04	3	0.5	0.0654	0.1963	0.0005	0.5577
2-5,30	0.05	2	0.5	0.0654	0.1308	0.0004	0.9172
2-5,135	0	0	0	0	0	0	0
2-6,40	0	0	0	0	0	0	0
3-1,45	0	0	0	0	0	0	0
3-1,145	0	0	0	0	0	0	0
3-2,100	0.08	4	0.5	0.0654	0.2617	0.0007	0.2349
3-3,45	0.03	1	0.3	0.0141	0.0141	3.8E-05	0.0751
3-3,145	0	0	0	0	0	0	0
3-4,80	0.2	1	0.7	0.1795	0.1795	0.0005	0.0366
3-5,45	0	0	0	0	0	0	0
3-5,110	0	0	0	0	0	0	0
3-6,80	0	0	0	0	0	0	0
4-1,28	0	0	0	0	0	0	0
4-1,130	0.03	1	0.6	0.113	0.113	0.0003	0.1029
4-2,70	0.25	3	0.3	0.0141	0.0424	0.0001	0.1023
4-3,28	0.1	1	0.15	0.0018	0.0018	4.8E-06	0.2647
4-3,130	0	0	0	0	0	0	0
4-4,70	0	0	0	0	0	0	0
4-5,28	0	0	0	0	0	0	0
4-5,130	0	0	0	0	0	0	0
4-6,74	0	0	0	0	0	0	0
5-1,28	0	0	0	0	0	0	0
5-1,135	0	0	0	0	0	0	0
5-2,70	0	0	0	0	0	0	0
5-3,28	0.26	1	0.3	0.0141	0.0141	3.8E-05	0.4315
5-3,135	0	0	0	0	0	0	0
5-4,83	0	0	0	0	0	0	0
5-5,28	0.243	1	0.5	0.0654	0.0654	0.0002	0
5-5,110	0	0	0	0	0	0	0
6-1,9	0	0	0	0	0	0	0
6-1,106	0	0	0	0	0	0	0
6-2,60	0.232	10	0.4	0.0335	0.3349	0.0009	4.2745
6-3,9	0	0	0	0	0	0	0
6-3,106	0	0	0	0	0	0	0
6-4,52	0	0	0	0	0	0	0
6-5,9	0	0	0	0	0	0	0
6-5,106	0.25	1	0.5	0.0654	0.0654	0.0002	0.0996
6-6,60	0	0	0	0	0	0	0
7-1,13	0	0	0	0	0	0	0
7-1,115	0	0	0	0	0	0	0
7-2,86	0	0	0	0	0	0	0
7-3,29	0.511	1	2	4.1867	4.1867	0.0113	0.9968

NO. = Number carbonate grains
Diameter is in mm.
MAR = Grams/cm^2/My
Volume is reported in mm^3

Analysis IRD from Site 580 Deep Sea Drilling Project Siltstone Data
Siltstone Density = .00265 g/mm^3 Sed. Rate(cm/my 5000

Sample	% SiltSt.	NO.	Mean Diameter	Volume	Total Volume	Mass	MAR
1-1, 20	0	0	0	0	0	0	0
1-1,120	30.8	3	2.75	10.884	32.651	0.0865	3.2412
1-2,70	0	0	0	0	0	0	0.0643
2-1,32	0	0	0	0	0	0	0
2-1,130	0	0	0	0	0	0	0
2-2,80	2.08	20	0.8	0.2679	5.3589	0.0142	0.0139
2-3,30	0	0	0	0	0	0	0
2-3,130	0	0	0	0	0	0	0
2-4,76	0	0	0	0	0	0	0
2-5,30	0	0	0	0	0	0	0
2-5,135	0	0	0	0	0	0	0
2-6,40	0	0	0	0	0	0	0
3-1,45	0	0	0	0	0	0	0
3-1,145	0	0	0	0	0	0	0
3-2,100	0	0	0	0	0	0	0
3-3,45	0	0	0	0	0	0	0
3-3,145	0	0	0	0	0	0	0
3-4,80	0	0	0	0	0	0	0
3-5,45	0	0	0	0	0	0	0
3-5,110	0	0	0	0	0	0	0
3-6,80	0	0	0	0	0	0	0
4-1,28	0	0	0	0	0	0	0
4-1,130	0	0	0	0	0	0	0
4-2,70	25	2	0.5	0.0654	0.1308	0.0003	0.1023
4-3,28	20	1	0.3	0.0141	0.0141	3.7E-05	0.5294
4-3,130	0	0	0	0	0	0	0
4-4,70	0	0	0	0	0	0	0
4-5,28	0	0	0	0	0	0	0
4-5,130	0	0	0	0	0	0	0
4-6,74	0	0	0	0	0	0	0
5-1,28	12.1	1	1	0.5233	0.5233	0.0014	0.0594
5-1,135	12.1	2	1	0.5233	1.0467	0.0028	0.2964
5-2,70	0	0	0	0	0	0	0
5-3,28	0	0	0	0	0	0	0
5-3,135	0	0	0	0	0	0	0
5-4,83	0	0	0	0	0	0	0
5-5,28	0	0	0	0	0	0	0
5-5,110	0	0	0	0	0	0	0
6-1,9	19.5	1	0.8	0.2679	0.2679	0.0007	0.4231
6-1,106	35.2	1	0.25	0.0082	0.0082	2.2E-05	0.1147
6-2,60	0	0	0	0	0	0	0
6-3,9	23.1	1	2.5	8.1771	8.1771	0.0217	0.4059
6-3,106	0	0	0	0	0	0	0
6-4,52	50	1	0.4	0.0335	0.0335	8.9E-05	0.0293
6-5,9	0	0	0	0	0	0	0
6-5,106	0	0	0	0	0	0	0
6-6,60	0	0	0	0	0	0	0
7-1,13	23.8	1	0.5	0.0654	0.0654	0.0002	0.0789
7-1,115	0	0	0	0	0	0	0
7-2,86	0	0	0	0	0	0	0
7-3,29	6.6	1	0.3	0.0141	0.0141	3.7E-05	0.1287

NO. = Number of lithic grains. MAR = grams/cm^2/My
Diameter is in mm. Volume = mm^3